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Peter Schilling
Amy Couzens
Joseph Barth

U.S. Census Bureau
Washington, DC 20233

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**Bridge Report for the Quarterly Tax Summary:
A Study of the Methodological Changes to the Local Property Tax Component
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Peter Schilling, Amy Couzens, Joseph Barth
Governments Division,
U.S. Census Bureau, Washington, D.C. 20233-0001

Introduction

In 2007, the National Research Council issued a report entitled *State and Local Government Statistics at a Crossroads*. This report was the culmination of a two-year review of the U.S. Census Bureau's Governments Division's programs that survey the economic activity of state and local governments, including state and local government finances, activities of public employee retirement systems, and employment and payroll of public employees. After a thorough review of these programs, the Committee on National Statistics (CNSTAT) issued 21 recommendations on data quality, statistical methodology, dissemination, analysis, and future challenges for the Governments Division.

The Quarterly Summary of State and Local Government Tax Revenue (QTax) provides national-level quarterly estimates of state and local tax revenue, as well as detailed tax revenue data for individual states. QTax is divided into three sections which use forms F-71, F-72 and F-73. The F-71 is used to obtain local government property tax data from tax collectors, the F-72 is used to obtain state government taxes, while the F-73 obtains non-property taxes from local governments.

Recommendation 4-11 from CNSTAT stated that the Governments Division should use the redesign of QTax to assess the quality of the sample frame, to develop a probability sample of local governments for non-property tax measurement, to streamline questionnaires, and to develop cost-effective estimation, variance estimation, editing, and imputation procedures that meet Census Bureau standards. In response to the CNSTAT recommendation, the Governments Division made the redesign of the QTax a priority. Although the redesign of QTax was already underway, the CNSTAT recommendation gave added impetus to the endeavor. In this paper, we report on a study of the methodological changes to the local property tax component (F-71) of the QTax. For six quarters, beginning with the fourth quarter of 2008 and continuing through the first quarter of 2010, data were collected simultaneously for both the original and modified survey designs. This study examines the differences in the local property tax estimates under the original and the new methodology.

Changes to the Sample Design

A county area consists of all local governments within a county and can include five different government types: county, city, town/township, special district, and school district. Parishes, boroughs and independent cities that are not designated as part of a county are all considered "county equivalents". The Census Bureau maintains a list of all counties or county equivalent administrative units.

To estimate local property taxes, a stratified sample of county areas was created from county areas divided into two groups or *strata*, based on population and tax revenues. Specifically, if a county area population exceeded a threshold value, or if its tax revenue exceeded a threshold value, then that county area was automatically included in the F-71 sample. But if a county area had a population below the population threshold and if its tax revenue was below the revenue threshold, then that county area could only be included in the F-71 sample by random selection. This method of automatically selecting units into a sample when they meet a particular criterion is also known as *sample selection with certainty* ¹.

After the certainty units were added to the F-71 sample, the non-certainty county areas underwent a second stage of stratification by cost code and population². This stratification was accomplished by developing a cost file for all counties in the U.S. prior to sample selection. Each county was assigned a cost code that indicated the number of tax collectors for that county. A cost code of one indicates the county government collects taxes for all local governments within that county area; a cost code of three indicates there are two to five tax collecting agencies for a county area; and a cost code of five indicates there are five or more tax collecting agencies in that county area. Using the three possible cost codes and county population, the non-certainty county areas were assigned to eleven different groups or strata. Sample sizes were assigned to each of the eleven strata and non-certainty units were then selected using a simple random sample method within each group or stratum.

The original sample design for the local property taxes (F-71) component of QTax was completed in 1997 and drawn from a universe that was based on the 1992 Census of Governments. The new F-71 sample design was completed in 2008 and drawn from a universe of 3,136 county areas that was based on the 2002 Census of Governments, as results from the 2007 Census of Governments were not yet available.

In the original F-71 sample design, a county area needed to have a population above 200,000 or tax revenues greater than \$100 million to be automatically included in the sample, or selected with certainty. The new F-71 sample design increased the population threshold to 350,000 and the tax revenue threshold to \$165 million for a county area to be selected with certainty. A total of 289 county areas were included

¹ Lohr, S. (1999).

² Craig T. (2008)

in the new F-71 sample using the certainty criteria. An additional 320 county areas were added to the new F-71 sample using random selection within the strata. Thus, the new F-71 sample had a total of 609 county areas; within these county areas are a total of 5,407 tax-collecting government agencies³. The number of tax-collecting government agencies in the new sample is essentially unchanged from the number of collecting agencies in the original sample.

Changes to Data Editing Methods

The data received from respondents each quarter are subject to editing to capture and minimize potential data errors. Edit bounds can be produced from a variety of different methods, but are ultimately based on a distribution of ratios that are being edited. For the local property tax (F-71) component of QTax, these ratios are calculated using a ratio expression incorporating current quarter and prior quarter property taxes for a local government.

Prior to the redesign, the edits consisted of a ratio of the amount of property tax being reported in the current quarter divided by the amount reported in the same quarter of the previous year. Under this original edit system, edit bounds were *hard coded*, or set to default values of 0.8 and 1.2. Thus, the amount of change in each local government's property taxes compared with the same quarter last year could be up to 20 percent greater or smaller before that unit was flagged for analyst review. The original edit strategy only applied to local governments that reported \$100,000 or more in local property taxes for both the current quarter and the same quarter last year.

Under the new editing system for F-71, the data are subjected to two types of edits: ratio edits and consistency edits⁴. Two different ratio edits are used. The first ratio edit (Edit 1) compares the current reported amount with the amount reported in the same quarter last year, using the same ratio as in the original editing strategy. The second ratio edit (Edit 2) compares the four-quarter sum ending in the current quarter with the corresponding four-quarter sum ending in the current quarter of the previous year. Expressions for these two ratio edits are given below.

$$\text{Edit 1: } \frac{Q_t}{Q_{t-4}} \qquad \text{Edit 2: } \frac{Q_t + Q_{t-1} + Q_{t-2} + Q_{t-3}}{Q_{t-4} + Q_{t-5} + Q_{t-6} + Q_{t-7}}$$

The new editing strategy also makes use of the Hidiroglou-Berthelot (HB) method⁵ rather than hard-coding to set the edit bounds. Use of the HB method is notable because it accounts for the size of ratio expression for local property tax values as well as the distribution of ratio data to set edit bounds in the current quarter. With

³ Couzens, A., Hogue, C. & Villena P. (2009).

⁴ *ibid*

⁵ Hidiroglou, M.A. & Berthelot, J.M. (1986).

HB bounds, priority is placed on capturing data errors that have the largest impact on the local property tax estimate. Comparing the new versus original edit systems, the likelihood of capturing important errors is increased while the overall number of edit failures is decreased⁶.

A consistency edit was also added to the new edit system. This consistency edit was used to identify local governments that had reported property taxes during the current quarter, but zero reported property tax collected during the same quarter in the previous year (“nothing to something”). Similarly, the consistency edit would also identify local governments with zero reported property taxes in the current quarter, but actual receipt of property taxes during the same quarter of the previous year (“something to nothing”). Local governments identified by the consistency edit were sorted by the property tax revenue reported either during the current quarter or same quarter in the previous year. To manage the overall edit workload, only governments with local property tax revenues in the top 20 percent of those “something to nothing” or “nothing to something” groups were identified for analyst review⁷.

Changes to Non-Response Methods for the QTax System

Imputation methods underwent fundamental changes during the redesign of the QTax local property tax survey (F-71). The original imputation strategy was to substitute or “pull forward” the property tax amount from the same quarter in the prior year for each county area with missing data. In practice, this technique of “pulling forward” reported values from a prior year could continue for years and would continue uninterrupted until a new response was received for that county area. More statistically defensible imputation methods were needed for the F-71 survey data.

The new imputation strategy requires that all units in the local property tax sample be assigned to groups of similar units or *imputation cells*. Deciding on a plan to form the imputation cells proved to be challenging, because every county operates according to its own tax collection rules and has unique tax collection patterns. After a review of the F-71 sample, the team working on the imputation redesign decided to form imputation cells by Census Bureau defined regions and type of government (cities, counties, townships, special districts, and school districts). This decision was made because reporting units in the same geographic area tend to have similar laws governing local tax collection⁸. Imputation cells were defined in such a way to preserve a high degree of similarity among units within a cell (in terms of government type, region, division, and population), but also guard against

⁶ Couzens, A., Hogue, C. & Villena P. (2009).

⁷ *ibid*

⁸ *ibid*

forming cells that would be too small to adequately impute missing data within the cell.

During this initial research period, the F-71 imputation redesign team combined similar imputation cells when it appeared unlikely that one or both cells would consistently meet the minimum performance criteria (15 respondents, 50 percent response rate) during production. Before imputation cells could be combined, a procedure had to be established to determine the order of operations and the criteria used to perform these tasks. The redesign team decided that imputation cells should be combined by *reporting pattern* first, where reporting pattern refers to which quarters during a year that county areas report local tax revenue. Next, within reporting pattern groups, similar units will be further grouped by region, then division, then by government type, and finally by population.

Currently, a total of 78 cells are defined at the start of the redesigned F-71 imputation process. However, if the number of respondents within any given cell is less than 15 or the total cell response rate is below 50 percent, then that cell must be collapsed into another cell prior to imputation. The imputation redesign team decided that when imputation cells must be collapsed, collapsing should occur in an opposite order to combining cells: first by population, then by government type, then by division, and finally by region (if needed).

The F-71 imputation redesign team also evaluated a number of possible imputation methods, but finally settled on two for production imputations: median growth rates and cell medians⁹. When historical data are available for a particular county area, imputation is conducted using a median growth rate applied to the reported value from the same quarter last year, since research has shown this approach is the best strategy for units with historical data. When historical data are not available for a county area, imputation is conducted using the adjusted cell mean property tax value.

The redesigned imputation strategy uses median growth rates when historical data exists for a county area and adjusted cell means when no historical data are available. However, imputed property tax revenues calculated in one quarter can eventually serve as historical data in future years. This has important implications for the way missing F-71 values will be imputed in the future; after the first four quarters of this bridge study (4th quarter 2008 through 3rd quarter 2009), every county area in the new F-71 sample has historical data available for all four quarters in a calendar year. Thus, an important transition occurs starting with the fifth quarter of this study (4th quarter, 2009): from that point on, all missing values in the new F-71 sample are imputed using median growth rates.

⁹ Couzens, A., Hogue, C. & Villena, P. (2009).

Changes to Estimation Methods

Methodological changes to the local property tax component of QTax did not include the statistical methods used to estimate the quarterly total of local property tax revenues over all county areas. For both the original and new F-71 samples, the estimate of the total was calculated as the weighted sum of the reported and imputed property tax revenues for each county area. As such, there will be no change in the final estimate due to estimation methodology.

However, as part of the methodological changes, new estimation capabilities have been introduced, which includes calculating the coefficient of variation (CV) for the estimates of the quarterly total of local tax revenues. A *coefficient of variation* is calculated by dividing the square root of the estimated variance (or the *standard error*) by the estimated value and gives a measure of the relative variability of an estimate¹⁰. Starting with this data release, the coefficients of variation will be published alongside the estimates of quarterly local tax revenue totals and provide added value to F-71 data users.

Sampling and Non-Sampling Error

Sampling error can be defined as the difference between the estimated value and the unknown true value that is due to observing only a sample of the universe rather than the entire universe. Use of the word “error” should not be understood as a mistake and is not an indication of a flaw in the sample design. These errors are present in nearly all samples and are not directly measurable except by means of a census. Since a new F-71 sample has been selected it is likely that there will be a change in estimates due to sampling error.

All surveys and censuses are subject to non-sampling errors. Non-sampling errors can be attributed to many sources: the inability to obtain information from all of the surveyed cases, reporting errors and biases, mistakes in recording, keying, or classifying the data, errors in collection or processing, and inadequate coverage of the universe.

Explicit measures of the effects of these non-sampling errors are not available. However, to minimize non-sampling error, data were reviewed for reasonableness and consistency, and every effort was made to acquire accurate responses from all survey participants. Coverage errors may have an effect on the accuracy of estimates for this survey as the sampling frame may not contain all local governments.

¹⁰ Lohr, S. (1999).

Results

Table 1 provides sample sizes, response rates, and total quantity response rates (TQRR's) calculated from the original and new sample units over the six-quarter period for this study (4th quarter 2008 to 1st quarter 2010). Before examining the results from Table 1, an important distinction should be made between types of response rates. A *response rate* measures the proportion of the selected sample that is represented by the responding units. Response rates in Table 1 are simply the number of reporting county areas divided by the total number of county areas in the sample for a particular quarter. In contrast, a *total quantity response rate* is the proportion of the estimated (weighted) total of a data item reported by tabulation of units in the sample or from sources determined to be equivalent quality to the reported data¹¹. Though the TQRR can be calculated in a variety of different ways, the values in Table 1 are simply the weighted sum of respondent property tax revenues divided by estimated totals of quarterly local property tax revenues. Note that both quantities in our TQRR calculations can be found in Table 2.

Table 1: Comparison of sample size, response rates and total quantity response rates for original and new sample designs

| | Original Sample | | | New Sample | | |
|----------------------|-----------------|------------|------|------------|-----------|------|
| Qtr. | Samp. Size | Resp. Rate | TQRR | Samp. Size | Resp Rate | TQRR |
| 1 st 2010 | 5,325 | 61.7 | 76.6 | 5,533 | 65.1 | 83.0 |
| 4 th 2009 | 5,325 | 65.4 | 86.4 | 5,532 | 64.5 | 81.0 |
| 3 rd 2009 | 5,325 | 66.1 | 83.4 | 5,532 | 64.0 | 84.5 |
| 2 nd 2009 | 5,354 | 71.3 | 88.5 | 5,532 | 67.4 | 86.3 |
| 1 st 2009 | 5,355 | 71.8 | 91.5 | 5,532 | 70.2 | 83.7 |
| 4 th 2008 | 5,377 | 69.4 | 88.0 | 5,532 | 66.4 | 83.9 |

Source: Census Bureau, Quarterly Summary of State and Local Tax Revenue

Table 2 compares respondent totals versus estimated totals of quarterly local property tax revenues using county areas taken from both the original and new F-71 sample designs. As discussed earlier, the respondent total is a weighted sum of reported local property tax revenues, while the estimated total estimates the quarterly total of all local property tax revenues. Table 2 also provides coefficients of variation (CV's) for the estimated total of quarterly local property tax revenues.

¹¹ "U.S. Census Bureau Statistical Quality Standards" (2010).

Table 2: Comparison of respondent total versus estimated total of quarterly local property tax revenue for original and new sample designs

| Qtr. | Original Sample | | | New Sample | | | Diff. (%) |
|----------------------|-----------------|---------------|-------|---------------|---------------|-------|-----------|
| | Resp. Total | Est. Total | CV | Resp. Total | Est. Total | CV | |
| 1 st 2010 | 80,552,761.4 | 105,167,967.3 | 0.019 | 91,710,127.5 | 110,433,517.6 | 0.025 | 5.0 |
| 4 th 2009 | 143,990,766.9 | 166,495,742.8 | 0.015 | 151,984,551.3 | 187,632,479.2 | 0.042 | 12.7 |
| 3 rd 2009 | 64,568,772.8 | 77,403,940.4 | 0.018 | 68,423,047.6 | 80,981,905.5 | 0.016 | 4.6 |
| 2 nd 2009 | 71,130,170.0 | 80,356,862.2 | 0.023 | 72,303,467.0 | 83,739,571.6 | 0.025 | 4.2 |
| 1 st 2009 | 97,587,403.9 | 106,705,550.4 | 0.019 | 95,167,226.5 | 113,703,354.8 | 0.021 | 6.6 |
| 4 th 2008 | 138,264,180.4 | 157,148,004 | 0.015 | 142,668,472.5 | 169,948,866.4 | 0.015 | 8.1 |

Source: Census Bureau, Quarterly Summary of State and Local Tax Revenue

Discussion of Results

The results from Table 1 show that the final sample sizes for the new sample design were slightly larger than those of the original sample design, with size increases ranging from 2.8 to 3.8 percent. Table 1 also shows that the original sample design generally outperformed the new in terms of response rates and TQRR's at the outset of the six quarter period, but the differences narrowed over time and by the final quarter, the new sample design was outperforming the original. This was probably due to the fact that the respondents in the original sample were used to receiving and filling out the F-71 form, while respondents in the new sample were not used to participating in the F-71 survey. During the first three quarters of this study (4th 2008 to 2nd 2009), response rates for the original sample design exceeded the new by 3.0, 1.6, and 3.9 percent. This difference decreased over the next two quarters and by the final quarter (1st 2010), the response rate for the new sample design exceeded the original by 3.4 percent. Similarly, over the first three quarters of the study, TQRR's for the original sample design exceeded the new by 4.1, 7.8 and 2.2 percent, respectively. By the final quarter (1st 2010), the TQRR for the new sample design exceeded the original by 6.4 percent. These results demonstrate that response rates and TQRR's for the new sample design can be consistent with, or outperform that of the original sample design. As the overlap period between the two different F-71 samples ends, more non-response followup will be targeted toward local governments selected in the new sample.

Results observed from Table 2 show that respondent totals for local property tax revenues for the new sample design generally exceed that for the original, with the exception of the second quarter (1st 2009). However, the estimated total of quarterly local property tax revenue for the new sample design exceeds that of the original over all six quarters in this study. Table 2 also shows that differences between the original and new sample designs are relatively moderate in terms of percentage difference between estimated totals of quarterly local property tax revenues. In five of the six quarters of the study, the percentage difference is less than 10 percent, with the fifth quarter (4th 2009) being the exception. The relative

differences in Table 2 also appear to be higher for the first and fourth quarters compared to the second and third quarters of a calendar year, though there is not enough data to discern a trend.

The coefficients of variation (CV's) for the estimated quarterly local property tax in Table 2 were generally very similar in value for both the original and new sample designs. During the first three quarters (4th 2008 to 2nd 2009), CV's for the new sample design were slightly larger than those for the original sample design, while in the fourth quarter of the study, the CV for the original sample design was slightly larger. In the fifth quarter, the CV of the new sample design was sharply higher than in earlier quarters and also substantially larger than that of the original sample design. In the sixth quarter, the CV of the new sample design fell back to the range observed in the first four quarters of this study. Overall, we expect CV's for the original and new sample designs to be relatively close in value due to the high degree of consistency between the two sample designs.

Conclusions

Based on the observed results, the redesign of the local property tax component of QTax does not have a negative impact on the data. These methodological changes should not cause a severe break in the F-71 time series; time series analyses could be done across the break, but data users should be cognizant of the changes when attempting to interpret results over this period. All of the modifications that have been introduced produce an F-71 data product comparable to the one before, but with slight improvements and more statistical rigor. The improved estimation capabilities and publication of coefficients of variation (CV's) with every total quarterly estimate of local property taxes offer more credibility to these data.

Now that these methodological changes have been successfully implemented in the F-71 component of QTax, we plan to turn our attention to the local *non-property* tax component (F-73), which will require a similar overhaul within the next year. We expect to see more changes with the F-73 versus the F-71 component, since we will be replacing a non-probability survey with a probability survey. In addition, further modification to the local property tax component will eventually be necessary since the F-71 sample will be redesigned again before 2015 when results of the 2012 Census of Governments will be utilized.

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